EXPLORESPACE TECH
TECHNOLOGY DRIVES EXPLORATION

LIVE: Excavation, Construction, and Outfitting
NASA Space Technology Mission Directorate
May 2022

STMD welcomes feedback on this presentation
See RFI 80HQTR22ZOA2L_LIVE at nspires.nasaprs.com for how to provide feedback
If there are any questions, contact HQ-STMD-STAR-RFI@nasaprs.com

LIVE: Autonomous excavation, construction & outfitting capabilities targeting landing pads/structures/habitable buildings utilizing in situ resources

Thrusts	Outcomes
Go Rapid, Safe, and Efficient Space Transportation	• Develop nuclear technologies enabling fast in-space transits. • Develop cryogenic storage, transport, and fluid management technologies for surface and in-space applications. • Develop advanced propulsion technologies that enable future science/exploration missions.
Land Expanded Access to Diverse Surface Destinations	• Enable Lunar/Mars global access with ~20t payloads to support human missions. • Enable science missions entering/transiting planetary atmospheres and landing on planetary bodies. • Develop technologies to land payloads within 50 meters accuracy and avoid landing hazards.

Live
Sustainable Living and Working Farther from Earth
	• Develop exploration technologies and enable a vibrant space economy with supporting utilities and commodities
	  • Sustainable power sources and other surface utilities to enable continuous lunar and Mars surface operations.
	  • Scalable ISRU production/utilization capabilities including sustainable commodities on the lunar & Mars surface.
	  • Technologies that enable surviving the extreme lunar and Mars environments.
	  • Autonomous excavation, construction & outfitting capabilities targeting landing pads/structures/habitable buildings utilizing in situ resources.
	• Enable long duration human exploration missions with Advanced Life Support & Human Performance technologies.

Explore Transformative Missions and Discoveries	• Develop next generation high performance computing, communications, and navigation. • Develop advanced robotics and spacecraft autonomy technologies to enable and augment science/exploration missions. • Develop technologies supporting emerging space industries including: Satellite Servicing & Assembly, In Space/Surface Manufacturing, and Small Spacecraft technologies. • Develop vehicle platform technologies supporting new discoveries. • Develop transformative technologies that enable future NASA or commercial missions and discoveries

TX 07.2 Mission Infrastructure, Sustainability, and Supportability - Provide landing sites, blast containment shields, landing aids.

TX 03 Advanced Power – Receive power; Provide excavation and construction services necessary for power infrastructure

TX 07.1 In-Situ Resource Utilization – Provide regolith for commodities and feedstock production; receive resource information and manufacturing/construction feedstock.

TX 07.2.5 & TX 12.1 Advanced Materials and Dust Mitigation – providing and using technologies for surviving extreme environments

TX 10 Autonomous Systems – Receive Autonomous Systems & Robotics technologies for complex Excavation, Construction, & Outfitting operations

TX07.2 Assembly, TX12.3 Mechanical Systems - Shared capability areas with Servicing & Assembly (OSAM)

TX 12.4 Manufacturing – Receive manufactured parts for Lunar surface Construction and Outfitting from Adv. Manufacturing

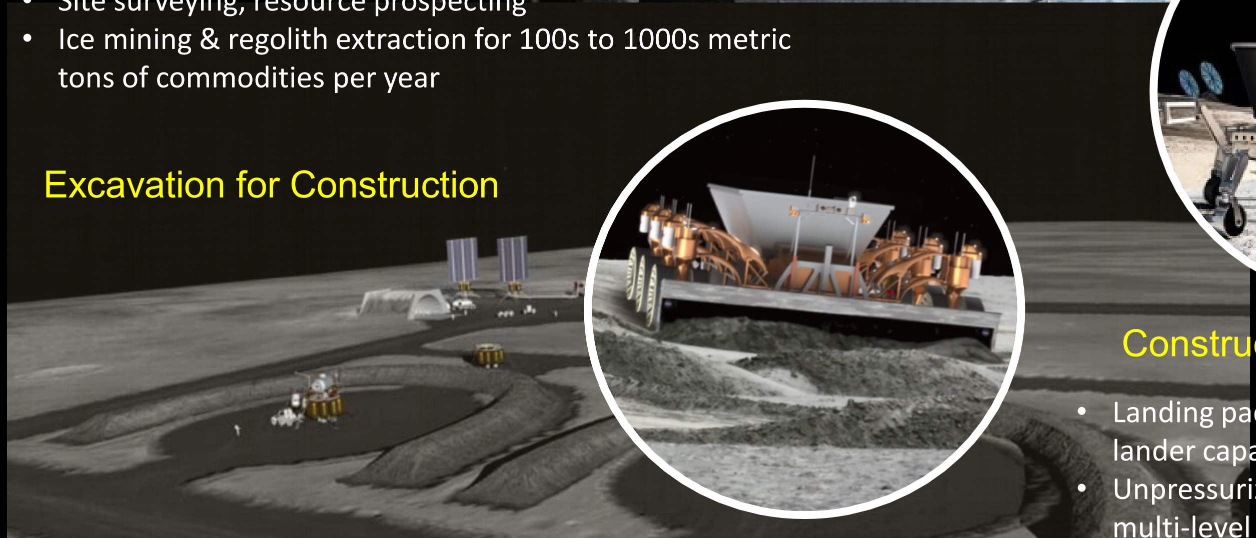
Autonomous Lunar Excavation, Construction, & Outfitting

targeting landing pads, structures, habitable buildings utilizing in-situ resources

Excavation for ISRU-based Resource Production

- Site surveying, resource prospecting
- Ice mining & regolith extraction for 100s to 1000s metric tons of commodities per year

Excavation for Construction



- Site preparation for construction: obstacle clearing, leveling & trenching
- Construction materials production utilizing in-situ resources
  - 100s to 1000s metric tons of regolith-based feedstock for construction projects
  - 10s to 100s metric tons of metals and binders

Construction and Outfitting

- Landing pad construction demo scaling to human lander capable landing pads
- Unpressurized structure evolving to single and then multi-level pressurized habitats
- Outfitting for data, power & ECLSS systems
- 100-m-diameter landing pads, 10s km of roads, 1000s m^3 habitable pressurized volume

Sustainable Off-Earth Living & Working

- Commercial autonomous excavation and construction of landing pads, roads and habitable structures
- Fully outfitted buildings to support a permanent lunar settlement and vibrant space economy
- Extensible to future SMD missions and Mars settlement

Not all activities depicted are currently funded or approved. Depicts "notional future" to guide technology development vision.

Plan to Develop Excavation, Construction, and Outfitting Capabilities

- Overall Plan
  - Technology development roadmaps are being developed and requirements defined leading to a logical buildup of ECO capabilities and scale that culminate in a series of ground and lunar demonstrations
  - Technology investments to span entire TRL space
  - External collaboration and partnerships to leverage terrestrial civil engineering expertise
  - Leverage APL/LSIC Working Groups to perform reviews, studies, & integration
- Next Steps
  - Complete current technology development activities, and begin planning of next phase of developments.
  - Complete roadmap and demonstration plans - coordination with ISRU, AS&R, Power, Thermal, Dust, EE capability areas
  - Continue modest Pilot projects addressing top priorities and initiate new projects (top priorities presented herein)
  - Focus on high-priority gaps to complement current investments
  - Identify and plan ground and lunar surface demos necessary for gap closure

Excavation for ISRU

Capability Description, Outcomes, and State of the Art

Capability Description

- Autonomous resource excavation and delivery to ISRU plant –1000s t/year
- Distance traveled with repeated trafficking – 1000s km/year
- Recharging – 100s times (assuming no on-board PV charging)
- Operational Life – 5 years
- Reliability and Repair – MTBF = 10 lunar days, MTTR = <2 hrs

Outcomes

- Regolith for O_2
- Icy Regolith for H_2O and volatiles - hydrogen, carbon oxides, hydrocarbons, and ammonia
- Regolith for ISRU-based construction feedstocks and binders – Metals, Silicon, Slag

State of the Art: Current lunar excavation technologies can only dig into surface regolith, not deep or icy regolith.

Capability or KPP	SoA	Threshold	Goal
Excavation	Surveyor Scoop: < 10kg	100s t/year	1000s t/year
Dist. Traveled	Opportunity Rover: 46 km	100s km/year	1000s km/year
Repeated Trafficking	Apollo rover: 5X	100s X	1000s X
Operational Range between resource & delivery site	None	500 m	> 1 km
Recharge Cycles (assuming no on-board PV charging)	None	10s X	100s X
Operational Lifetime	Chinese Yutu Rover Many lunar day/night cycles	1 year	5 years
Reliability & Repair	None	MTBF: 1 lunar day MTTR: <24 hrs	MTBF: 10 lunar days MTTR: <2 hrs

ISRU resource prospecting and geotechnical characterization (ISRU dependency)

MTBF = Mean Time Before Fail

MTTR = Mean Time to Repair

Excavation for ISRU

Current Investments and Investment Needs

- Current Investments
  - ➢ ISRU Pilot Excavator (IPE) in development for CLPS demo – high TRL
  - ➢ Regolith Scoops: COLDArm (CY24), SAMPLR (CY22) demonstrations
  - ➢ Break the Ice Lunar Challenge (Centennial Challenge Phase 2, March 2022)
  - ➢ New 2022 SBIR Topic: Lunar Surface Excavation, Construction, and Outfitting
  - ➢ Regolith simulant development
- Needed Areas with Limited* or No Investment
  - ➢ Low mass rugged robotic platforms
  - ➢ Autonomy for high throughput operations
  - ➢ Modularity and interfaces
  - ➢ Regolith flow/interaction with implements
  - ➢ Power and wireless recharging
  - ➢ Autonomous maintenance and repair
  - ➢ Wear-resistant materials and wear characterization
  - ➢ Long-life lubricants, motors, avionics
  - ➢ Dust mitigation for actuators, seals, joints, mechanisms
  - ➢ Dust-tolerant thermal control system

* Limited in scope and/or funding

ISRU resource prospecting and geotechnical characterization (ISRU dependency)

Resource excavation and delivery

Excavation for Construction

Capability Description, Outcomes, and State of the Art

Capability Description - Similar to Excavation for ISRU plus…

- Site survey – geotechnical and topography
- Load, Haul, Dump
- Bulk regolith manipulation – berms, piles, and overburden
- Level, grade, and compact
- Rock removal and gathering
- Trenching

Outcomes

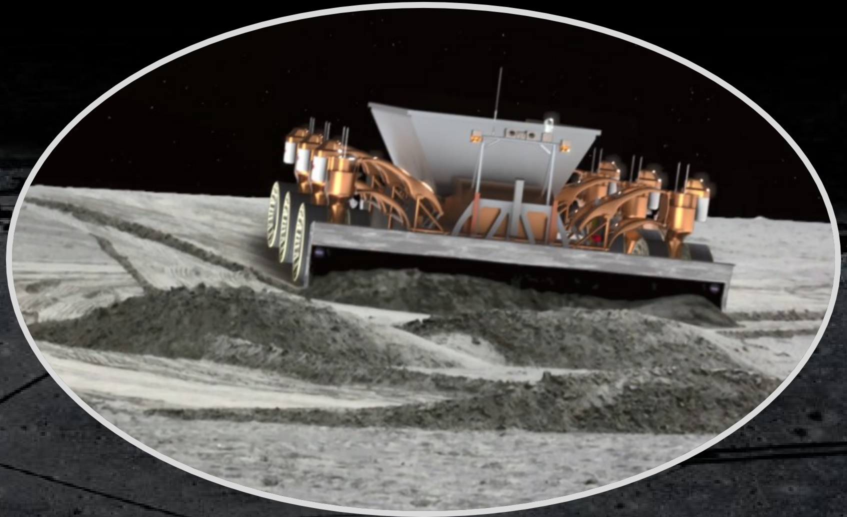
- Site preparation for construction - 1000s of m^2 of prepared surface
- Provide bulk regolith berms and overburden for shielding

SoA: Excavation for construction has never been attempted on an extraterrestrial body. Prototypes have been built at low TRL.

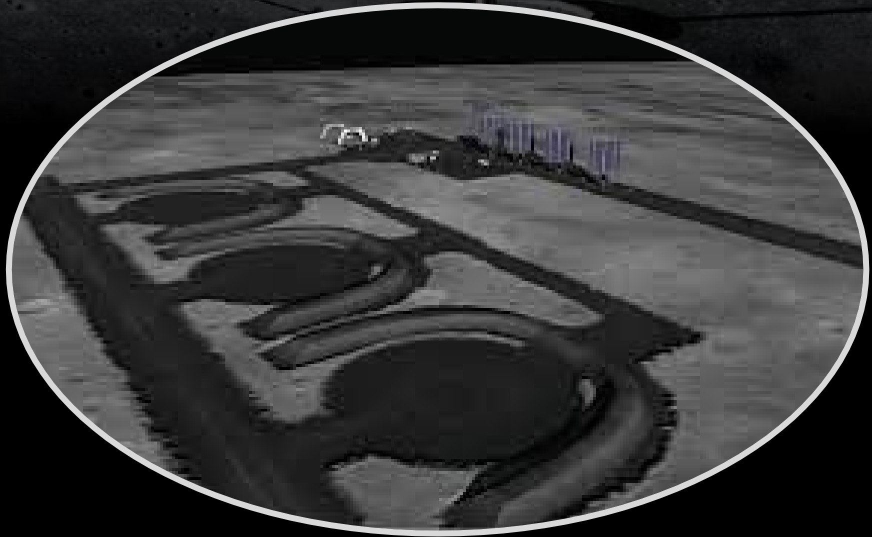
Similar KPPs as Excavation for ISRU, plus the following:

Capability or KPP	SoA	Threshold	Goal
Bulk density and bearing and shear strength measurement of regolith	cone penetrometer, shear vane, coring	1 measurement per 100 m^2	10 autonomous measurements per 100 m^2
Topology characterization	LIDAR, Photogrammetry	10mm resolution	5mm resolution
Bulk Regolith Manipulation – berm building and piling	None	4 m tall	7 m tall
Site Level, Grade & Compact (1.9 g/cc)	None	25 m radius	50 m radius
Rock Removal and Gathering	Rake (Apollo): 1-10 cm	<10 cm	<50 cm
Trenching	Apollo & lunar surveyor scoop: several cm's deep	1.0 m deep	3.0 m deep

Leveling and grading



Early-phase infrastructure



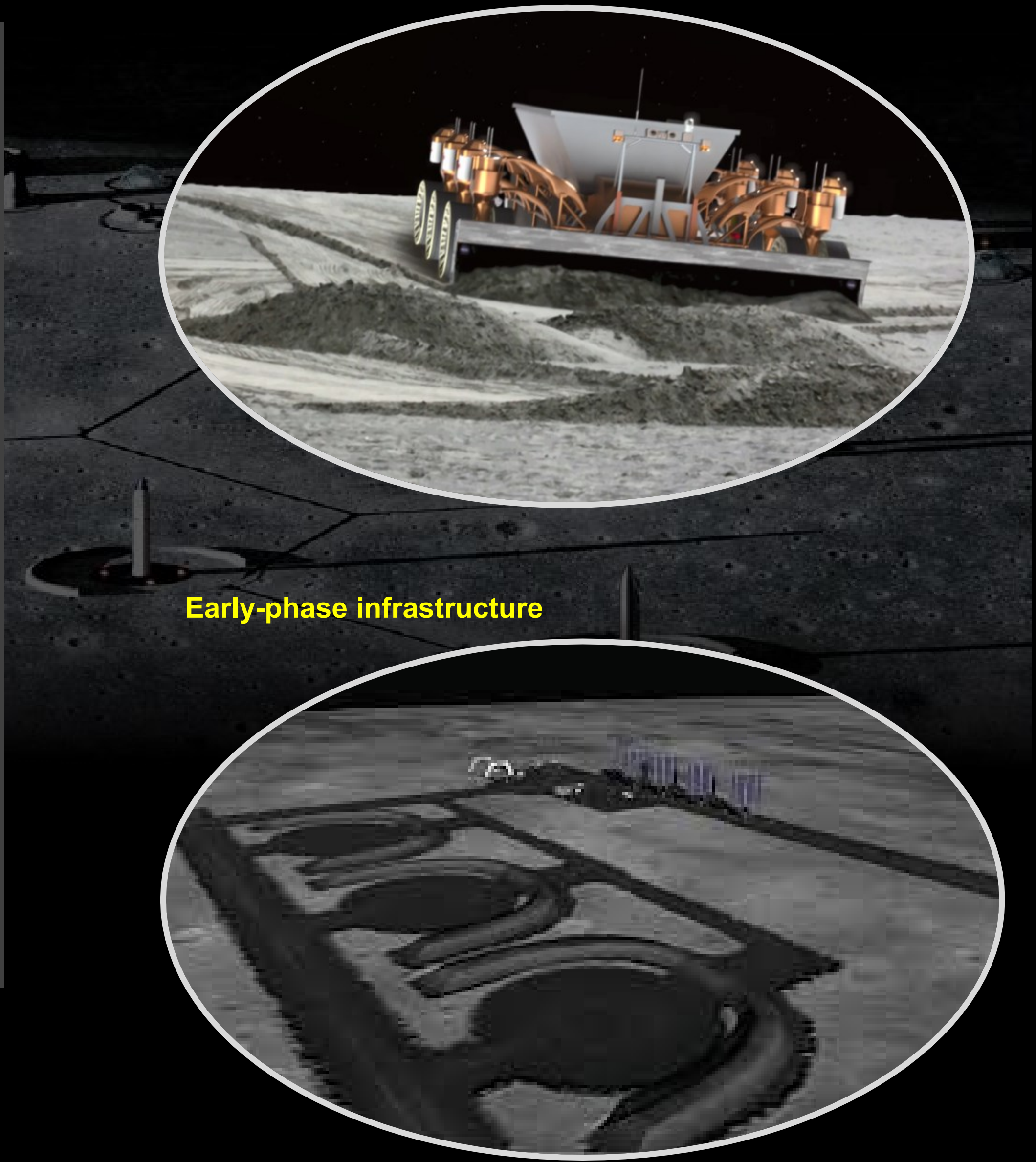
Excavation for Construction

Current Investments and Investment Needs

- Current Areas of Investment
  - Lunar Surface Technology Research (LuSTR) topic: **Autonomous Systems for Excavation and Site Preparation of Lunar Regolith**
    - STMD Space Technology Research Grants
    - Aligned with LSII focus areas
    - University-led with 40% industry participation allowed
    - Anticipate one award in Spring of 2022

- Needed Areas with Limited or No Investment
  - Similar needs as Excavation for ISRU
  - Additional needs include:
    - Site prep inspection techniques and sensor systems
    - Implements: excavation, haul, dump, rock handling, grading, leveling, compaction, berm building, trenching
    - **Need mid-TRL investments in this area**

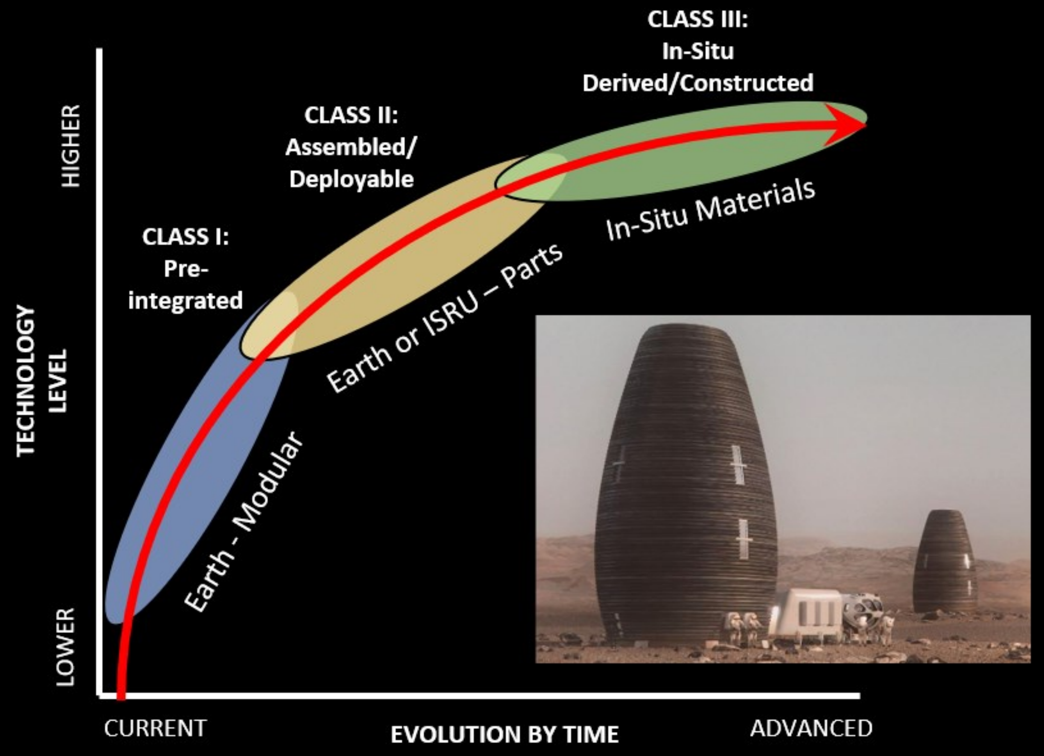
Leveling and grading



Surface Construction Classifications

Delivery of large habitable volumes will require a different approach from the "cans on landers" concepts that have been depicted for decades

- **How can we build?**



Notes:
- Class II structures can include ISRU derived components
- Shared capability areas with Servicing & Assembly, e.g., autonomous assembly, docking interfaces, outfitting, V&V

Classification	Key Characteristics
CLASS I **Pre-integrated** 	• Earth Manufactured • Pre-Integrated & Tested Prior to Launch • Space Delivered with Immediate Habitation Capability • Volume Constrained by Launch Vehicle Shroud Size • Mass Constrained by Launch Vehicle Mass Capability
CLASS II **Surface Deployed & Assembled** 	• Earth-sourced or ISRU-derived • Requires Surface Deployment, Assembly & Outfitting • May Include Partial Integration of Subsystems • Critical Subsystems are Earth Based and Tested Prior to Launch • Requires Assembly & Checkout Prior to Human Occupancy • Larger Volumes Capable (e.g., Transhab ~3X the Volume of a Standard ISS Module) • Reduced Restriction on Volume Due to Launch Vehicle Shroud Size • Restricted to Launch Mass Capability. Deliver on Multiple Vehicles
CLASS III **In-Situ Derived and Constructed** 	• Manufactured In-situ, Derived from Local Resources (Lunar or Mars) • In-space Constructed • Requires Robotic Construction Capability & Infrastructure • Requires Robotic and Human Labor During Construction • Requires Integration of Subsystems • Critical Subsystems are Earth Based and Tested Prior to Launch • Larger Volumes Capable and No Longer Constrained by Launch Vehicle (Constrained by Limitations of Construction Equipment) • Construction Equipment Constrained to Launch Vehicle Mass and Volume.

Surface Construction

Capability Description, Outcomes, and State of the Art

Capability Description:

- *Class II*: Assembly of components into built-up structures (e.g., Earth-sourced or ISRU-based truss, panel, paver, bricks); deployment of human-rated preassembled or inflatable structures
- *Class III*: In-situ construction (e.g., 3D printed construction)
- In-situ testing and inspection techniques for certification (material and structural)
- Structural enhancement and repair
- Construction System: design for lunar survivability, reliability, and maintenance

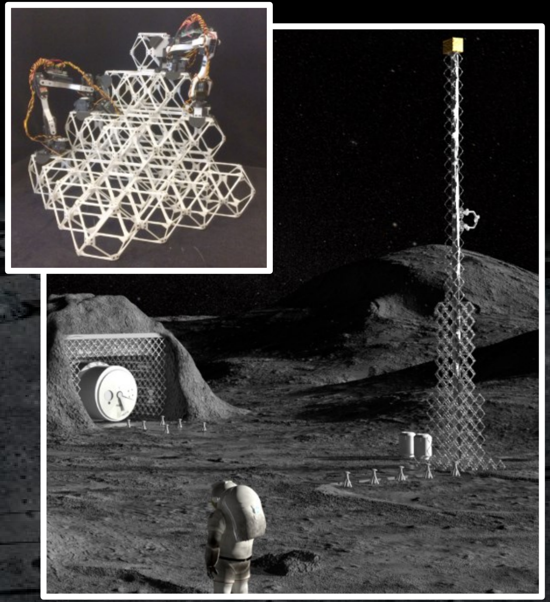
Outcomes

- 100-m-diameter launch/landing pads (LLPs)
- 10s km of roads
- Towers (100+m tall for Power and over-horizon Communication)
- Blast containment shield (BCS)– 7m-tall, 100s m long
- Shelters & habitats (1000s m^3 volume) to provide asset and crew protection (thermal, radiation, etc.)

SoA: Extraterrestrial surface construction has never been attempted. Terrestrial prototypes at low TRL.

Capability or KPP	SoA	Threshold	Goal
Class II: Deployable and assembled structures	ISS: deployable trusses for solar arrays and radiators; inflatable volumes (not human-rated).	Autonomous assembly of tower and Blast Cont. Shield with some ISRU-based components	Autonomous assembly of shelter and habitat structures with 100% ISRU based components
Class III: In-situ construction	Low TRL development work	ISRU-based LLPs, BCS, shelters and habitats with limited Earth-sourced materials	100% ISRU-based LLPs, BCS, shelters and habitats
Autonomous in-situ testing & inspection	ISS inspection: visual, thermography, eddy current, ultra-sound, strain gage, accels.	Voids & cracks, material strength and stiffness. Material degradation	full volumetric inspection of material and structural properties w/ real-time corrective actions
Structural enhancement & repair	ISS enhancement: swap-out of modular components and orbital replacement units ISS structural repair: none	Manual repair; post-construction enhancement/modification	Selected auto. repair and post-construction enhancement
System Operational Lifetime	None	2 year	10 years
Reliability & Repair	None	MTBF: 2 lunar days, MTTR: <24 hrs	MTBF: 10 lunar days, MTTR: <2 hrs

Class II: Assembly & Deployables



Class III: In-situ Construction

MTBF = Mean Time Before Failure

MTTR = Mean Time to Repair

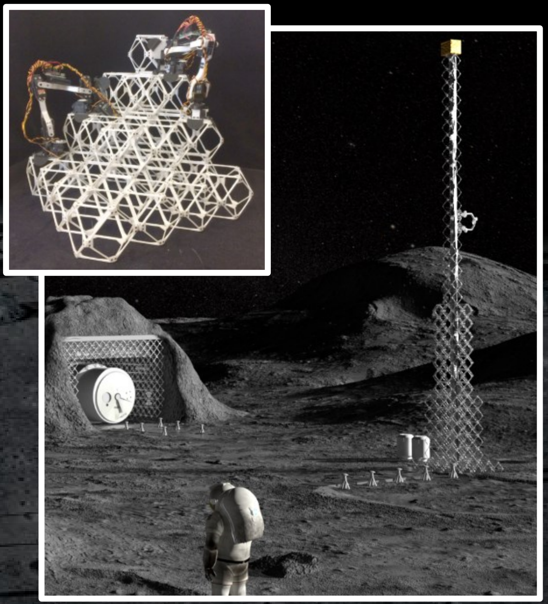
Surface Construction

Current Investments and Investment Needs

- ## Current Areas of Investment
  - Class II: Deployable and assembled structures
    - Precision Assembled Space Structure (PASS)
    - Automated Reconfigurable Mission Adaptive Digital Assembly Systems (ARMADAS)
    - Deployable Composite Boom (DCB)
  - Class III: In-situ construction
    - Moon-to-Mars Planetary Autonomous Construction Technology (MMPACT)
    - Relevant Environment Additive Construction Technology (REACT/ACO)
    - NIAC/STRG/SBIR

- ## Needed Areas with Limited or No Investment
  - Architectural and ConOps studies (limited - MMPACT & REACT)
  - Surface characterization to inform foundation design
  - Building requirements and standards
  - Construction equipment (similar needs as Excavation)
  - Inspection methods (e.g., process, materials, structures)
  - Autonomy for complex construction and inspection tasks (very limited – MMPACT)

Class II: Assembly & Deployables



Class III: In-situ Construction

Outfitting

Capability Description, Outcomes, and State of the Art

Capability Description

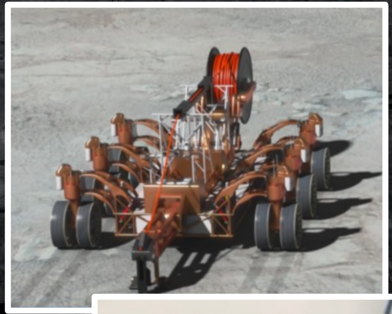
- The process by which a structure is transformed into a useable system by <u>in-situ</u> installation of subsystems.
  - Subsystem installation
  - In-situ testing/validation and inspection techniques with associated metrology
  - Structural repair and enhancement

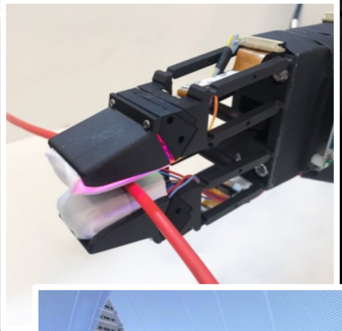
Outcomes (affects most systems that are not landed in operational self-contained state)

- Power, Lighting, Data & Communications distributed through system
- ECLSS
- Fluids & Gasses (ISRU products) managed and stored.
- Widows and Hatches
- Interior Furnishing

SoA: Preintegrated structures, with manual in-situ upgrades and repairs.

Capability or KPP	SoA	Threshold	Goal
Conductor/Cable and Piping/Tubing line management (LM)	ISS Preintegrated on ground, EVA upgrades and repairs	LM during construction using Earth-sourced harness (50% auto.). Manual repair; Post-construction manual LM for facility enhancement.	LM during construction using ISRU derived harness (100% auto.). Selected auto. repair and enhancement/expansion.
Penetration management (PM) including through pressure vessels (Habitats, tanks, shelters, blast shield etc.)	ISS Preintegrated on ground, <u>NO</u> post launch penetrations added.	PM during construction using Earth-sourced materials (50% auto.). Manual repair; Post-construction manual PM for facility enhancement.	PM during construction using ISRU derived material (100% auto.). Selected auto. repair and enhancement
Attachment of secondary systems to structures.	ISS Preintegrated some IVA and EVA rerouting.	Attachment to arbitrary surfaces and structures.	Reversible attachment to arbitrary surfaces and structures on 3D printed structures.
Metrology to verify installation and functionality.		Pressure test piping, geometry charac. for assembly verification, load test of foundations, continuity/signal strength for communications/wiring.	Continuous process monitoring, equivalency testing, structural health monitoring for 3D printed habitat by 2035.



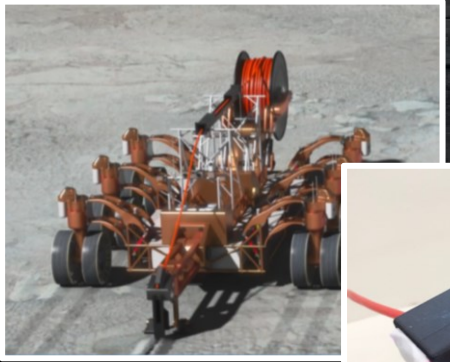


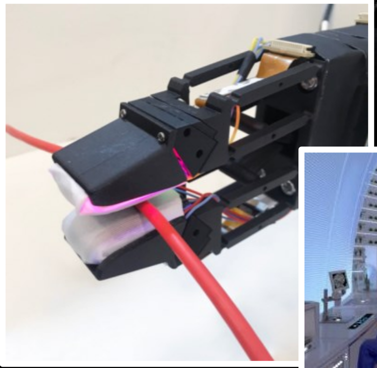
Outfitting

Current Investments and Investment Needs

- **Current Areas of Investment**
  - In-Space Manufacturing
    - Redwire Regolith Print (RRP): Printing parts using polymer binders with regolith filler
    - On-demand manufacturing of metals, Recycle & Reuse
  - MSFC CAN with Branch Technologies (limited scope)
    - Synthetic biology polymers (Stanford University and Ames)
    - Multi-functional, lightweight/movable partitions

- **Needed Areas with Limited or No Investment**
  - Architectural and ConOps studies
  - Outfitting requirements and standards
  - Outfitting technologies (e.g., lighting, harnesses, beacons, sensors, fluids, HVAC)
  - Design of pressure vessel connections/seals with penetrations
  - Common interface definition
  - Utility corridor design
  - Inspection methods & repairs
  - Autonomy for complex outfitting and inspection tasks





Autonomous Lunar Excavation, Construction, & Outfitting

targeting landing pads, structures, habitable buildings utilizing in-situ resources

Top Priority Activities

1. LSIC studies and reviews
   - What: roadmap and gap reviews for ECO, studies and working groups to help identify technology gaps and provide technical support in technology development planning, help w/ integration/collaboration with industry and DoD
   - Why: LSIC E&C WG provides a tremendous opportunity for collaboration with industry and academia in many needed technology areas

2. Modest mid-TRL Pilot projects to address known priorities (ground-based designs with path to flight, targeting operational systems and CLPS demos. Hardware development)
   - Site preparation (clearing, grading, compacting)
   - Tall Tower
   - Landing Pads (beacons, pad, blast shield, etc.)
   - Shelter construction and outfitting
   - ISRU materials production

3. Pre-formulation Studies of ECO systems and surface construction concepts
   - What: Solicit pre-formulation studies to produce ECO systems and surface construction concepts.
   - Why: Formulate new ideas for an evolvable and sustainable lunar settlement utilizing ISRU-based construction, including early infrastructure that can evolve to larger more complex construction as necessary materials and construction technologies mature. External collaboration/partnerships to leverage terrestrial expertise.
   - Outcome: Develop mission concepts, draft system-level requirements, assess performance, cost, and schedule feasibility; identify potential technology needs, and scope. Products: simulations, analysis, study reports, models, and mockups

Autonomous Lunar Excavation, Construction, & Outfitting

targeting landing pads, structures, habitable buildings utilizing in-situ resources

Top Technology Development Priorities

1. Excavation for Site Preparation and ISRU-based Commodities
   - What: Develop and demonstrate excavation capabilities needed for site preparation and construction, and regolith extraction for ISRU-based construction materials and commodities production (ground & lunar surface demonstrations)
   - Why:
     - Excavation technology needed to provide 1,000s of tons of regolith feedstock for infrastructure construction and ISRU-based commodities (ISRU Pilot Excavator 2026 demo opportunity)
     - Excavation and site preparation are required for all construction activities: **No mid-TRL funded projects currently**
     - Excavation can provide for some basic construction needs. Enables near term and achievable infrastructure emplacement using a combination of structural assembly, bulk regolith manipulation, and early in-situ manufacturing – e.g., paths and prepared surfaces, blast walls, berms, and regolith overburden for radiation, micrometeorite, and thermal protection (possible 2026 Scaled Construction Demo).

2a. ISRU-based Materials and Processes for Lunar Surface Construction
   - What: Develop/demonstrate viable ISRU-based materials and processes for the construction of horizontal and vertical extraterrestrial structures in lunar environment (sintered regolith, binder/regolith blend)
     - MMPACT, REACT/ACO
   - Why: Current SoA is to use prefabricated structures launched from Earth and is not a sustainable approach to lunar surface infrastructure development. The use of ISRU-based construction materials is expected to be the most cost-efficient methodology for development of a permanent sustainable human presence on the Moon (possible 2026 Scaled Construction Demo).

Autonomous Lunar Excavation, Construction, & Outfitting

targeting landing pads, structures, habitable buildings utilizing in-situ resources

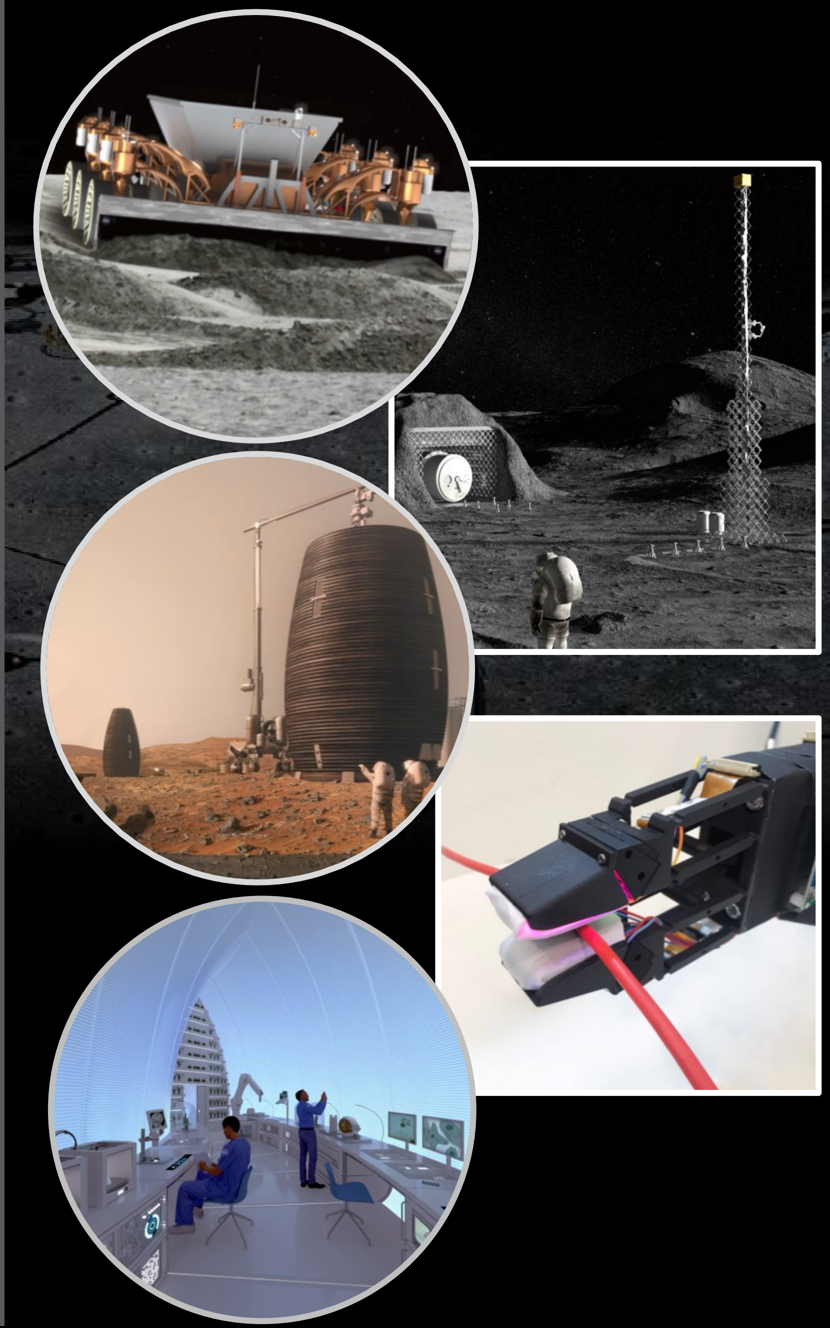
Top Priority Activities

2b. Large-scale Class II and Class III Construction

- What: Develop a combination of robotic assembly and ISRU-based construction systems capable of repeatable, reliable, autonomous construction of
  - Horizontal structures (e.g., landing pads, roads, dust-free zones)
  - Vertical structures (e.g., towers, blast containment shields, shelters, and habitats)
- Why:
  - Assembly of 50m+ tall towers for power and comm.
  - Pads, blast walls, and roads needed to control blast ejecta, mitigate dust, and enable trafficability
  - Unpressurized shelters and pressurized habitats needed for radiation, micrometeorite, and thermal protection of surface assets and crew.
  - Class II: Assembly of towers and blast shields, evolving to shelters and habitats (currently at a higher TRL than Class III). Earth-sourced parts can be used in early phases and replaced by ISRU-derived parts.
  - Class III: Goal to provide 100% ISRU-based construction solution. Technology can be phased into lunar infrastructure architecture as it matures. Start with smaller parts for assembly, later evolving into large-scale unitized structures.
  - Possible 2026 and/or 2028 Construction Demos.

Summary Plan to Develop Excavation, Construction, and Outfitting Capabilities

- Proposed Capability-Specific Activities to Achieve the Outcomes
  - Excavation for ISRU
    - EI-1: IPE for a sub scale ISRU Oxygen production demonstration
    - EI-2: ISRU Pilot Plant excavation technology demonstration (targeting icy regolith)
    - EI-3: Excavator for full scale autonomous ISRU consumables production demonstration
  - Excavation for Construction
    - EC-1: Subscale Surface Preparation demo – site survey, basic functions, roads
    - EC-2: Subscale launch/landing pad (LLP) preparation – autonomous mobility platform
    - EC-3: Full scale autonomous site preparation for roads, LLP, and foundations
  - Surface Construction – Class II: Surface Assembly
    - SCII-1: Assembly Tech Dev. And Ground Demos
    - SCII-2: Horiz. & Vert. Truss Assembly – Landing Pad Blast Containment Shield and Power Tower
    - SCII-3: Full scale shelter (increasing complexity w/ outfitting)
    - SCII-4: Full scale habitat (CCII-3 evolved to a pressurized volume) w/ ISRU-based components
  - Surface Construction – Class III: ISRU-based Construction
    - SCIII-1: Tech Dev. And Ground Demos
    - SCIII-2: Initial lunar surface proof of concept material processing and deposition
    - SCIII-3/4: Subscale and full scale landing pad demos w/ outfitting
    - SCIII-5: Full scale autonomous vertical construction w/ outfitting
  - Outfitting
    - O-1: Horizontal harness integration for roads and LLPs (beacons, lights, cameras)
    - O-2: Tower & shelter vertical harness integration (lights, radiation sensors, cameras)
    - O-3: Habitat harness + fluid/gas integration + interior outfitting
    - O-4: ISRU plant setup and integration to storage/transportation facilities
    - O-5: Lander refueling



Acronyms

- ACO – Announcement of Collaboration Opportunity
- APL – Applied Physics Lab
- ARMADAS – Automated Reconfigurable Mission Adaptive Digital Assembly Systems
- AS&R – Autonomous Systems & Robotics
- BCS – Blast Containment Shield
- CAN – Cooperative agreement notice
- CLPS – Commercial Lunar Payload Services
- COLDArm – Cold Operable Lunar Deployable Arm
- DCB – Deployable Composite Boom
- DoD – Department of Defense
- E&C – Excavation and Construction
- ECLSS – Environmental Control and Life Support System
- ECO – Excavation, Construction, and Outfitting
- EE – Electrical Engineering
- EVA – Extravehicular Activity
- HVAC – Heating, Ventilation, and Air Conditioning
- IPE – ISRU Pilot Excavator
- ISRU – In-situ Resource Utilization
- ISS – International Space Station
- IVA – Intravehicular Activity
- KPP – Key Performance Parameter
- LIDAR – Light Detection and Ranging
- LLP – Launch/Landing Pads
- LM – Line Management
- LSIC – Lunar Surface Innovation Consortium
- LSII – Lunar Surface Innovation Initiative
- LuSTR – Lunar Surface Technology Research
- MMPACT – Moon-to-Mars Planetary Autonomous Construction Technology
- MSFC – Marshall Space Flight Center
- MTBF – Mean Time Before Failure
- MTTR – Mean Time to Repair
- NIAC – NASA Innovative Advanced Concepts
- OSAM – On-orbit Servicing, Assembly, and Manufacturing
- PASS – Precision Assembled Space Structure
- PM – Penetration Management
- PV – Photovoltaic
- REACT – Relevant Environment Additive Construction Technology
- RRP – Redwire Regolith Print
- SAMPLR - Sample Acquisition, Morphology Filtering and Probing of Lunar Regolith
- SBIR – Small Business Innovative Research
- STMD – Science Technology Mission Directorate
- SMD – Science Mission Directorate
- SoA – State of the Art
- STRG – Space Technology Research Grants
- TRL – Technology Readiness Level
- TX – Taxonomy
- V&V – Verification and Validation
- WG – Working Group